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Ophiothrix fragilis and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment

MarLIN – Marine Life Information Network
Marine Evidence–based Sensitivity Assessment (MarESA) Review

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Please note. This MarESA report is a dated version of the online review. Please refer to the website for the most up-to-date version [https://www.marlin.ac.uk/habitats/detail/1068]. All terms and the MarESA methodology are outlined on the website (https://www.marlin.ac.uk)

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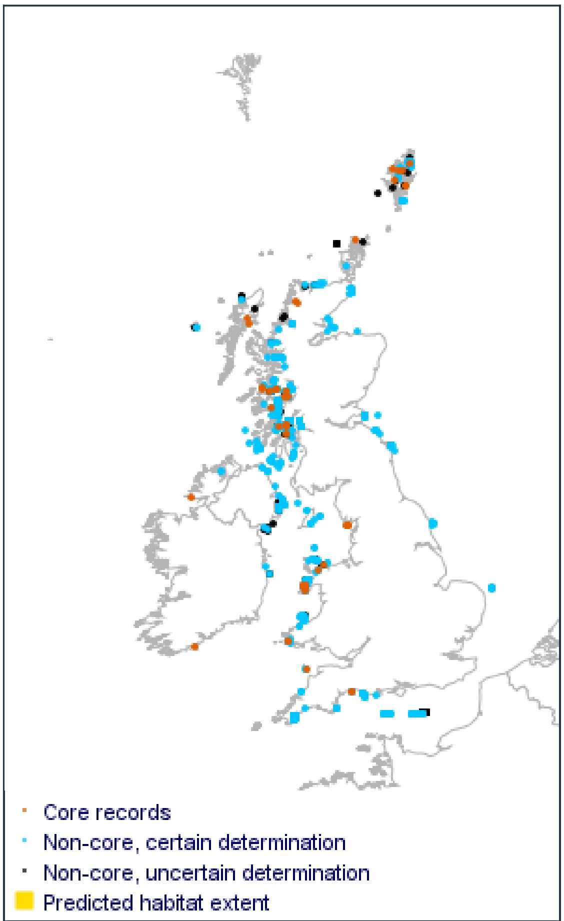
***Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment**
Photographer: Keith Hiscock



17-09-2018
Biotope distribution data provided by EMODnet Seabed Habitats (www.emodnet-seabedhabitats.eu)

Researched by Eliane De-Bastos & Jacqueline Hill **Refereed by** Admin

Summary

UK and Ireland classification

EUNIS 2008	A5.445	*Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment
JNCC 2015	SS.SMx.CMx.OphMx	*Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment
JNCC 2004	SS.SMx.CMx.OphMx	*Ophiothrix fragilis* and/or *Ophiocomina nigra* brittlestar beds on sublittoral mixed sediment
1997 Biotope		

Description

Circalittoral sediment dominated by brittlestars (hundreds or thousands m^2) forming dense beds, living epifaunally on boulder, gravel or sedimentary substrata. *Ophiothrix fragilis* and *Ophiocomina nigra* are the main bed-forming species, with rare examples formed by *Ophiopholis aculeata*.

Brittlestar beds vary in size, with the largest extending over hundreds of square metres of sea floor and containing millions of individuals. They usually have a patchy internal structure, with localized concentrations of higher animal density. *Ophiothrix fragilis* or *Ophiocomina nigra* may dominate separately or there may be mixed populations of the two species. *Ophiothrix* beds may consist of large adults and tiny, newly-settled juveniles, with animals of intermediate size living in nearby rock habitats or among sessile epifauna. Unlike brittlestar beds on rock, the sediment based beds may contain a rich associated epifauna (Warner, 1971; Allain, 1974; Davoult & Gounin, 1995). Large suspension feeders such as the octocoral *Alcyonium digitatum*, the anemone *Metridium senile* and the hydroid *Nemertesia antennina* are present mainly on rock outcrops or boulders protruding above the brittlestar-covered substratum. The large anemone *Urticina felina* may be quite common. This species lives half-buried in the substratum but is not smothered by the brittlestars, usually being surrounded by a 'halo' of clear space (Brun, 1969; Warner, 1971). Large mobile animals commonly found on *Ophiothrix* beds include the starfish *Asterias rubens*, *Crossaster papposus* and *Luidia ciliaris*, the urchins *Echinus esculentus* and *Psammechinus miliaris*, edible crabs *Cancer pagurus*, swimming crabs *Necora puber*, *Liocarcinus* spp., and hermit crabs *Pagurus bernhardus*. The underlying sediments also contain a diverse infauna including the bivalve *Abra alba*. Warner (1971) found that numbers and biomass of sediment dwelling animals were not significantly reduced under dense brittlestar patches.

Depth range

5-10 m, 10-20 m, 20-30 m, 30-50 m

Additional information

-

Listed By

- none -

Further information sources

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G G G JNCC

Sensitivity review

Sensitivity characteristics of the habitat and relevant characteristic species

SS.SMx.CMx.OphMx is a circalittoral biotope occurring on mixed sediment, often including cobbles, pebbles, gravel and sand, and dominated by dense mats of brittlestars (hundreds or thousands/m^2). This biotope is mainly found on the upper faces of moderately exposed and sheltered areas, subject to strong to weak tidal streams. *Ophiothrix fragilis* and *Ophiocomina nigra* are the main bed-forming species, with rare examples formed by *Ophiopholis aculeata*. Brittlestar beds vary in size, and *Ophiothrix fragilis* or *Ophiocomina nigra* may dominate separately or there may be mixed populations of the two species, with sediment-dwelling *Ophiura albida* occurring occasionally among them. The underlying fauna in brittlestar beds on mixed sediment does not appear to be restricted in numbers or growth by the carpet of brittlestars (Hughes, 1998b) and unlike brittlestar beds on rock, the sediment based beds may contain a rich associated epifauna (Warner, 1971; Allain, 1974; Davoult & Gounin, 1995). Large sessile species often observed in this biotope include octocoral *Alcyonium digitatum* on rock outcrops or boulders protruding above the substratum, and large anemone *Urticina felina*, which is not smothered by the brittlestars, usually surrounded by a 'halo' of clear space. Large mobile animals commonly found include starfish *Asterias rubens* and *Crossaster papposus*, urchins *Echinus esculentus*, and hermit crabs *Pagurus bernhardus*. The underlying sediments also may contain a diverse infauna including the bivalve *Abra alba* (Connor *et al*., 2004). The dense beds of brittlestars are the main characterizing feature of this biotope and their removal would likely result in the biotope being lost. Additionally, there are no known examples of species that are obligate or specialist associates of brittlestar beds. Therefore, the sensitivity assessment focuses on the main bed-forming species of brittlestar, *Ophiothrix fragilis* and *Ophiocomina nigra*.

Resilience and recovery rates of habitat

The biotope is characterized by dense mats of brittlestars. There is disagreement concerning the lifespan of the main bed forming brittlestar *Ophiothrix fragilis*. Davoult *et al.* (1990) suggested a lifespan of 9 -20 months. Taylor (1958, quoted in Gorzula, 1977) recorded that *Ophiothrix* reached a disc diameter of about 14 mm in two years, and that most individuals died after spawning in their second summer. However, other researchers have considered the animals to be much longer-lived. Gorzula (1977) quotes evidence that Swedish *Ophiothrix* can live for up to eight years. A lifespan of over nine years has been suggested based on counts of growth bands in the skeletal arm plates of *Ophiothrix* (Gage, 1990). It is possible that growth rates may vary widely in different areas, or that the different varieties of *Ophiothrix fragilis* recognised by French workers may have contrasting population dynamics.

Ophiothrix fragilis has an extended breeding season running roughly from April to October (Smith, 1940; Ball *et al*., 1995). In the Dover Strait, the main period of larval settlement was in September/October, but settlement also occurred in February, April and June (Davoult *et al*., 1990). Maximum population densities (approximately 2000 individuals /m^2) were found during the main recruitment period in September (Davoult *et al*., 1990). A similar seasonal pattern was found by Brun (1969) in the Isle of Man, where newly-settled juveniles were found in August and September. Peak juvenile numbers occurred in November in a Bristol Channel population (George & Warwick, 1985). In Kinsale Harbour, Ireland, post-settlement juveniles could be found throughout the year, with maximum numbers (up to 1000 juveniles /m^2) in October (Ball *et al*., 1995). Mortality was high, leading to low levels of recruitment into the adult population. All studies agree that recruits initially settle on the arms of adults. Lost populations may not always be replaced because settlement of larvae of *Ophiothrix fragilis* is highly dependent on hydrographic conditions and consequently may be unpredictable. In the strong water currents of the English Channel, larvae can disperse up to 70-100 km and establish populations elsewhere (Pingree & Maddock, 1977). Therefore, if hydrographic conditions change recruitment may fail and lost populations may not be replaced. For example, dense aggregations of *Ophiothrix fragilis* in the Plymouth area have not recovered since their decline in the 1970's. It was suggested that changes in the oceanographic cycle affecting the western Channel resulted in increased predation pressure from *Luidia ciliaris* and also recruitment failure of *Ophiothrix fragilis* (Holme, 1984). If any adults remain, aggregations may re-establish as individual brittlestars tend to crawl back and forth across water currents until a conspecific is found (Broom, 1975).

Ophiocomina nigra grows slowly and lives for up to 14 years (Hughes, 1998b). Juvenile *Ophiocomina* appear not to settle among adults. The Firth of Clyde populations studied by Gorzula (1977) were each dominated by a single size-class of animals, suggesting that each *Ophiocomina* bed is formed by a single settlement of juveniles, which thereafter receives little or no recruitment.

Other species often observed in this biotope include *Asterias rubens*, *Urticina felina*, and *Alcyonium digitatum*. Hiscock *et al.* (2010) recorded the succession of the biological community on the wreck for 5 years following the sinking of the ship *Scylla*, which was intentionally sunk on March 2004 in Whitsand Bay, Cornwall to act as an artificial reef. Initially the wreck was colonized by opportunistic species /taxa; filamentous algae, hydroids, serpulid worms and barnacles. *Asterias rubens* settled in large number within the first year of sinking and persisted throughout the observations. *Alcyonium digitatum* was first recorded within the first year after the vessel was sunk but colonies did not become a visually dominant component of the community until 2009 (5 years after the vessel had been sunk). *Urticina felina* colonized ex-HMS *Scylla* in the third of the vessel being on the seabed.

Resilience assessment: Removal of the brittlestar *Ophiothrix fragilis* and *Ophiocomina nigra* species would likely result in the biotope being lost and/or re-classified. Minor damage to individual brittlestars is likely to be repaired, missing arms that are shed as part of an escape/disturbance response can be regrown (Tillin & Tyler-Walters, 2014). Recovery from impacts with a small spatial footprint may occur through migration of adults and some species such as *Ophiura spp*. are mobile, as shown by bait trapping experiments (Groenewold & Fonds, 2000). Where the majority of the population remain (resistance is High), and/or recruitment by adult mobility is possible resilience is likely to be **'High'**. Where impacts remove a significant proportion of the population, recovery will require larval recolonization, as well as adult migration. Sexual maturity is reached within 2 years and reproduction is annual and protracted providing a supply of larvae. However, brittlestars demonstrate sporadic and unpredictable recruitment (Buchanan, 1964), even though they have long-lived pelagic larvae with a high dispersal potential. Therefore, where a significant part of the population is lost (resistance is **Low** or **None**), recovery is likely to be **'Medium'** (2-10 years). The evidence suggests that Ophiothrix fragilis' recruits initially settle on the arms of adults, but it is not clear whether the presence of adults is a requirement for successful larval re-colonization. The recruitment observations that occurred on *Scylla* suggest that other species occurring in this biotope, including *Asterias rubens*, *Urticina felina*, and *Alcyonium digitatum*, are likely to have medium resilience, apart from *Asterias rubens* for which resilience is considered likely to be high.

NB: The resilience and the ability to recover from human induced pressures is a combination of the environmental conditions of the site, the frequency (repeated disturbances versus a one-off event) and the intensity of the disturbance. Recovery of impacted populations will always be mediated by stochastic events and processes acting over different scales including, but not limited to, local habitat conditions, further impacts and processes such as larval-supply and recruitment between populations. Full recovery is defined as the return to the state of the habitat that existed prior to impact. This does not necessarily mean that every component species has returned to its prior condition, abundance or extent but that the relevant functional components are present and the habitat is structurally and functionally recognizable as the initial habitat of interest. It should be noted that the recovery rates are only indicative of the recovery potential.

Hydrological Pressures

	Resistance	Resilience	Sensitivity
Temperature increase (local)	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

Ophiothrix fragilis is widely distributed in the eastern Atlantic from Norway to South Africa and *Ophiocomina nigra* from Norway to the Azores and Mediterranean (Hayward & Ryland, 1995b). Other component species in the biotope also have a widespread distribution in the north east Atlantic. Consequently, these species are exposed to temperatures both above and below those found in the British Isles and their distribution is not limited by temperature. In the Dutch Oosterschelde Estuary fluctuations in the abundance of *Ophiothrix fragilis* between 1979 and 1990 appeared to be driven by winter temperatures (Leewis *et al.*, 1994). When winter temperatures increased in 1979-80 and 1987-88, populations of brittlestars increased enormously, and occupied 60-90% of the available hard substratum in layers up to 5 cm deep. Populations were reduced to less than 10% following the cold winters in 1978-79, 1984-85 and 1985-86. Thus, increases in temperature may be beneficial to populations. However, short-term acute changes in temperature are noted to cause a reduction in the loading of subcutaneous symbiotic bacteria in echinoderms such as *Ophiothrix fragilis*. Reductions in these bacteria are probably indicative of levels of stress and may lead to mortality (Newton & McKenzie, 1995).

Sensitivity assessment. The distribution of *Ophiothrix fragilis* and *Ophiocomina nigra* suggests that they are likely to be tolerant of an acute or chronic temperature increase at the pressure benchmark. Resistance is assessed as '**High**' and resilience as '**High'** (by default), so the biotope is therefore considered to be '**Not sensitive'** at the pressure benchmark.

Temperature decrease (local)	High Q: High A: Medium C: High	High Q: High A: High C: High	Not sensitive Q: High A: Medium C: High

Ophiothrix fragilis is widely distributed in the eastern Atlantic from Norway to South Africa and *Ophiocomina nigra* from Norway to the Azores and Mediterranean (Hayward & Ryland, 1995b). Other component species in the biotope also have a widespread distribution in the north east Atlantic. Consequently, these species are exposed to temperatures both above and below those found in the British Isles with distribution not limited by temperature. In the Dutch Oosterschelde Estuary fluctuations in the abundance of *Ophiothrix fragilis* between 1979 and 1990 appeared to be driven by winter temperatures (Leewis *et al.*, 1994). When winter temperatures increased in 1979-80 and 1987-88, populations of brittlestars increased enormously, and occupied 60-90% of the available hard substratum in layers up to 5 cm deep. Populations were reduced to less than 10% following the cold winters in 1978-79, 1984-85 and 1985-86. Thus, decreases in temperature may affect population densities. Short-term acute changes in temperature are noted to cause a reduction in the loading of subcutaneous symbiotic bacteria in echinoderms such as *Ophiothrix fragilis*. Reductions in these bacteria are probably indicative of levels of stress and may lead to mortality (Newton & McKenzie, 1995).

Sensitivity assessment. The distribution of *Ophiothrix fragilis* and *Ophiocomina nigra*, the characterizing species of the biotope, suggests that they are likely to be tolerant of an acute or chronic temperature decrease at the pressure benchmark. Thus, resistance is assessed as '**High**' and resilience as '**High'** (by default) and the biotope is therefore considered to be '**Not Sensitive'** at the pressure benchmark.

Salinity increase (local)	Low Q: NR A: NR C: Medium	Medium Q: High A: Medium C: Medium	Medium Q: Low A: Low C: Low

Echinoderms are stenohaline owing to the lack of an excretory organ and a poor ability to osmo- and ion-regulate (Stickle & Diehl, 1987; Russell, 2013) and unable to tolerate wide fluctuations in salinity. A review by Russell (2013) confirmed that *Ophiothrix fragilis* and *Ophiocomina nigra* have not been previously recorded in hypersaline conditions, although Pagett (1981) suggested that echinoderms may exhibit localised physiological adaption to reduced or variable salinities in near shore areas subject to freshwater runoffs. However, a circalittoral habitat is less likely to experience variable salinities, and resident species, therefore, less likely to be adapted to variation in salinity, as suggested by the results given by Pagett (1981).

Sensitivity assessment. There is little direct evidence of the effects of hypersaline conditions on *Ophiothrix fragilis* and *Ophiocomina nigra*. However, echinoderms are generally considered to be stenohaline (Stickle & Diehl, 1987; Russell, 2013). Therefore, an increase in salinity to >40 psu is likely to result in mortality and resistance is assessed as '**Low**' but with low confidence. Resilience is probably **'Medium**' so that sensitivity is therefore assessed as '**Medium**'.

Salinity decrease (local)	Low Q: High A: Medium C: Medium	Medium Q: High A: Medium C: Medium	Medium Q: High A: Medium C: Medium

Echinoderms are stenohaline owing to the lack of an excretory organ and a poor ability to osmo- and ion-regulate (Stickle & Diehl, 1987; Russell, 2013). This means that they are unable to tolerate wide fluctuations in salinity. Although brittlestar beds are generally found in fully marine conditions, Wolff (1968) observed dense aggregations of *Ophiothrix fragilis* occurring in salinities of 16 psu and even persisting down to 10 psu in the Oosterschelde Estuary. Russell (2013) reported that *Ophiocomina nigra* and *Ophiura albida* can tolerate 27.6‰ and 20‰ in experiments, respectively. Pagett (1981) suggested that localised physiological adaption to reduced or variable salinities may occur in near shore areas subject to freshwater runoffs However, a circalittoral habitat is less likely to experience variable salinities, and resident species, therefore, less likely to adapt to variation in salinity, as suggested by the results given by Pagett (1981).

Sensitivity assessment. The evidence suggests that a decrease in salinity may result in significant mortality of the biotope's defining species, *Ophiothrix fragilis*, especially as populations in the circalittoral may not be adapted to tolerate variations in salinity. Resistance is therefore assessed as '**Low**' and resilience as '**Medium**'. Sensitivity is therefore assessed as '**Medium'**.

Water flow (tidal current) changes (local)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Dense brittlestar beds are found in a range of water flows from sea lochs with restricted water flows to higher-energy environments on open coastlines (Connor *et al.*, 2004). In the Dover Strait, *Ophiothrix* beds experience current speeds of up to 1.5 m/s during average spring tides (Davoult & Gounin, 1995). Davoult & Gounin (1995) found that current speeds below 0.2 m/s were optimal for suspension feeding by *Ophiothrix fragilis*. If the velocity exceeded 0.3 m/s the animals ceased feeding, flattening themselves against the substratum and linking arms, so increasing their collective stability in the current. These values agree with those found by Warner (1971).

Similarly strong tidal streams (1.0-1.2 m/s) were also recorded over beds in the Isle of Man (Brun, 1969). In both locations (Isle of Man and the Dover Strait), *Ophiothrix* densities of up to 2000 individuals/m^2 were recorded. Hughes (1998b) suggested that high density aggregations could probably only be maintained where strong currents can supply enough suspended food. Food requirements probably set a lower limit on the current regime of areas able to support brittlestar beds. However, above a certain water speed (0.25 m/s) the feeding arms are withdrawn from the water column (Warner & Woodley, 1975; Hiscock, 1983). At water speeds above about 0.28 m/s individuals or even small groups may be displaced from the substratum and they have been observed being rolled along the seabed by the current (Warner, 1971). Living in dense aggregations may reduce displacement by strong currents (Warner & Woodley, 1975). *Ophiocomina nigra* is usually found in fairly sheltered sites with some water movement, and tends to become more dominant in deeper water than *Ophiothrix* (Connor *et al.*, 2004), which suggests a lower resistance to changes in water flow.

Sensitivity assessment. The evidence available suggests that brittlestars have behavioural adaptations to changes in water flow (Tillin & Tyler-Walters, 2014). Increased flow rates, increases suspension and transport of organic particles and can enhance feeding rates. If the flow is too strong, brittlestars may flatten, link arms, or withdraw arms into sediment. At lower flow rates species may switch to deposit feeding. Thus, although brittlestar beds can tolerate increased water flow over tidal cycles a long-term increase will probably prevent the population feeding and over a period of a year this is likely to cause the loss of the population. A decrease in water flow could potentially have an effect on some of the characterizing species of the biotope and may alter species richness as a result of sediment deposition. These are not considered to alter the character of the biotope. However, this brittlestar dominated biotope occurs in a range of water flows, so the change in the water flow experienced by mid-range populations of the characterizing species is unlikely to have an impact at the pressure benchmark. The biotope is considered to have '**High**' resistance and '**High**' resilience, and are therefore assessed as '**Not Sensitive'** at the benchmark level.

Emergence regime changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Changes in emergence are '**Not Relevant'** to this biotope, which is restricted to fully subtidal/circalittoral conditions. The pressure benchmark is relevant only to littoral and shallow sublittoral fringe biotopes.

	Resistance	Resilience	Sensitivity
Wave exposure changes (local)	High Q: Low A: Low C: Low	High Q: Low A: Low C: Low	Not sensitive Q: Low A: Low C: Low

Records indicate that SS.SMx.CMx.OphMx occurs in moderately exposed and sheltered areas (Connor *et al*., 2004). Connor *et al*. (2004) also suggested that the biotope occurs over a wide range of depths, although mainly in bands 10-20 m and 20-30 m, and that this means that wave action was not severe on the seabed as to displace the dense mat of brittlestars. A decrease may increase siltation and limit food supply for the dominant suspension feeding community but only where tidal flow is also reduced.

Sensitivity assessment: An increase or decrease in wave height at the pressure benchmark is unlikely to be significant in wave exposed examples of the biotope. As brittlestar beds require strong to moderate water movements, water flow is probably a more important source of water movement in sheltered examples of the biotope. Therefore, brittlestar beds probably have a '**High**' resistance to a change in significant wave height at the pressure benchmark. Resilience is assessed as '**High**', by default, and the biotope is considered '**Not Sensitive**' at the benchmark level.

Chemical Pressures

	Resistance	Resilience	Sensitivity
Transition elements & organo-metal contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Adult echinoderms such as *Ophiothrix fragilis* are known to be efficient concentrators of heavy metals including those that are biologically active and toxic (Ag, Zn, Cd and Co) (Hutchins *et al*., 1996). There is no information available regarding the effects of this bioaccumulation. Gounin *et al*. (1995) studied the transfer of heavy metals (Fe, Mn, Pb, Cu and Cd) through *Ophiothrix* beds. They concluded that heavy metals ingested or absorbed by the animals transited rapidly through the body and were expelled in the faeces and did not appear to accumulate in their tissues. Studies by Deheyn & Latz (2006) at the Bay of San Diego found that heavy metal accumulation in brittlestars occurs both through dissolved metals as well as through diet, to the arms and disc, respectively. Similarly, Sbaihat *et al*. (2013) measured concentrations of heavy metals (Cu, Ni, Cd, Co, Cr and Pb) in the body of *Ophiocoma scolopendrina* collected from the Gulf of Aqaba, and found that most concentration was found in the central disc rather than arms and no simple correlations could be found between contaminant and body length. It is logical to suppose that brittlestar beds would be adversely affected by major pollution incidents such as oil spills, or by continuous exposure to toxic metals, pesticides, or the antiparasite chemicals used in cage aquaculture. So far, however, there are no field observations of epifaunal brittlestar beds being damaged by any of these forms of pollution, and there seems to be no evidence of the toxicity effects of heavy metal accumulation on brittlestars.

Hydrocarbon & PAH contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Echinoderms tend to be very sensitive to various types of marine pollution (Newton & McKenzie, 1995). Adult *Ophiothrix fragilis* have been documented to be intolerant to hydrocarbons (Newton & McKenzie, 1995). The sub-cuticular bacteria that are symbiotic with *Ophiothrix fragilis* are reduced in number following exposure to hydrocarbons. Exposure to 30,000 ppm oil reduces the bacterial load by 50% and brittlestars begin to die (Newton & McKenzie, 1995). The water-accumulated fraction of diesel oil has been found to be acutely toxic to *Ophiothrix fragilis* and *Ophiocomina nigra*, although no field observations of beds being damaged by hydrocarbon pollution have been found (Hughes, 1998b).

Untreated oil (e.g. from oil spills) is not a risk, since it is concentrated mainly at the surface, and circalittoral biotopes are likely to be protected by their depth. If oil is treated by dispersant, the resulting emulsion will penetrate down the water column, especially under the influence of turbulence (Hartnoll, 1998).

Synthetic compound contamination	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed** but evidence is presented where available.

Echinoderms tend to be very sensitive to various types of marine pollution (Newton & McKenzie, 1995) but there is no more detailed information than this broad statement. In laboratory experiments Smith (1968) found the concentration of BP1002 (the detergent used in the *Torrey Canyon* oil spill clean-up) needed to kill the majority of *Ophiocomina nigra* was 5 ppm. Although there are no known examples of brittlestar beds being damaged by chemical pollutants such as pesticides or anti-parasite chemicals used in aquaculture, it is logical to suppose they would be adversely affected.

Radionuclide contamination	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

Adult echinoderms such as *Ophiothrix fragilis* are known to be efficient concentrators of radionuclides (Hutchins *et al*., 1996). However, there was no information available about the effect of this bioaccumulation.

Introduction of other substances	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

This pressure is **Not assessed**.

De-oxygenation	Medium Q: Medium A: Medium C: Medium	High Q: High A: High C: High	Low Q: Medium A: Medium C: Medium

Cole *et al.* (1999) suggested possible adverse effects on marine species exposed to dissolved oxygen concentrations below 4 mg/l and probable adverse effects below 2mg/l. However, *Ophiothrix fragilis* is known to have a low respiration rate (Migné & Davoult, 1997b), and experiments by Rosenberg *et al.* (1991, cited in Diaz & Rosenberg, 1995) suggested that the higher tolerance to hypoxia shown by *Amphiura chiajei* compared to *Amphiura filiformis* could also be linked to lower respirations rates, although both these brittlestars species were considered to be resistant to moderate hypoxia (Diaz & Rosenberg, 1995, references therein).

Stachowitsch (1984) observed a mass mortality of benthic organisms in the Gulf of Trieste, northern Adriatic Sea, caused by the onset of severe hypoxia (oxygen depletion) in the near-bottom water. A wide variety of organisms were affected, including burrowing invertebrates, sponges, and the brittlestar *Ophiothrix quinquemaculata*, a dominant component of the local epifaunal community. This event was likely caused by a combination of unfavourable weather and tidal conditions, at the same time as a period of maximal organic input from coastal pollution and dying phytoplankton. Water exchange in the Gulf was poor, and the area tended to accumulate sediment and suspended organic material. Very high productivity in the water column, combined with sewage input throughout the summer tourist season, probably led to the consumption of most of the dissolved oxygen by microbial activity. Mortality occurred when the oxygen-deficient water mass extended to the sea floor (Stachowitsch, 1984).

Sensitivity assessment: The evidence presented suggests that some species of brittlestar are likely to tolerate moderate levels of hypoxia. However, Stachowitsch (1984) observed a mass mortality of brittlestar *Ophiothrix quinquemaculata* within 2-3 days of the onset of a hypoxia event. Resistance of the biotope is assessed as '**Medium**' and recovery assessed as '**High**' resulting in the sensitivity of the biotope being considered '**Low'** at the pressure benchmark.

Nutrient enrichment	High Q: Medium A: High C: High	High Q: High A: High C: High	Not sensitive Q: Medium A: High C: High

It is thought that dense *Ophiothrix* beds may play an important role in local nutrient cycles by filtration and concentration of suspended particulate matter and by excretion of nitrogenous waste (Hughes, 1998b). Brittlestar beds are therefore likely to be able to resiste increased nutrient levels in the form of dissolved nutrients or particulate matter. For example, in the Bay of Brest in Brittany, Hily (1991) estimated that *Ophiothrix* beds with over 400 individuals/m^2 could filter the equivalent of 30% of the total water volume of the bay daily. The inflow of nutrient-rich stream water into the bay led to very high primary productivity, but eutrophication did not occur, because of the removal of particulate matter by the benthic community of brittlestars. A dense aggregation of *Ophiothrix* and *Ophiocomina* appeared to be unaffected by the presence of a salmon farm within 100 m (B. Ball pers. comm. in Hughes, 1998b). Since such farms often result in an increase in nutrients to the sea bed, brittlestar beds appear to be able to resiste some increase in nutrient levels (Hughes, 1998b). Raymont (1950) recorded an increase in populations of *Ophiocomina nigra* following the addition of fertilizers to the waters of an enclosed basin of Loch Sween, Argyll.

Sensitivity assessment. Due to the resistance of high levels of nutrient input demonstrated by species of brittlestars, brittlestar beds may be able to resiste nutrient enrichment. Resistance is assessed as '**High'** and resilience as '**High'** (by default) and the biotope is considered as '**Not Sensitive**' at the pressure benchmark that assumes compliance with good status as defined by the WFD.

Organic enrichment	High Q: Medium A: High C: Low	High Q: High A: High C: High	Not sensitive Q: Medium A: High C: Low

Organic enrichment may be beneficial to suspension feeders as a direct source of food and may indirectly enhance food supply where enrichment stimulates local growth of phytoplankton and diatoms. Raymont (1950) recorded an increase in *Ophiocomina nigra* populations following the addition of fertilizers to the waters of an enclosed basin of Loch Sween, Argyll. A dense aggregation of *Ophiothrix* and *Ophiocomina* was recorded in 1974 from a site at the mouth of Killary Harbour, western Ireland, and reported unchanged following subsequent establishment of a salmon farm within 100 m of the main beds (B. Ball, pers. comm. cited in Hughes, 1998b). However, high levels of organic enrichment would be expected to result in excessive sedimentation and hypoxia having deleterious effects on brittlestars and other suspension feeders. Stachowitsch (1984) reported that organic pollution may well have contributed to the environmental oxygen depletion causing mass mortality of brittlestar *Ophiothrix quinquemaculata* in the Gulf of Trieste.

The AZTI Marine Biotic Index (AMBI) is a biotic index to assess disturbance (including organic enrichment). Borja *et al*. (2000) assigned *Ophiothrix fragilis* to Ecological Group I (Species very sensitive to organic enrichment and present under unpolluted conditions (initial state) whereas Gittenberger & Van Loon (2011) assigned this species to Ecological Group II (Species indifferent to enrichment, always present in low densities with non-significant variations with time) (from initial state, to slight unbalance). *Ophiocomina nigra* has not been assigned an AMBI category. Although the unpublished Gittenberger & Van Loon (2011) report is an update on Borja *et al.* (2000), the former is a peer reviewed publication. Given that the evidence used in both cases is unclear, the degree of confidence is assessed as medium.

Sensitivity assessment: The evidence presented based on the AMBI scores conflicts and considered with caution. This biotope is generally found in areas with some water movement and this is likely to disperse organic matter reducing organic material load. Resistance to organic enrichment is assessed as '**High**' and resilience as '**High**'. The biotope is therefore assessed as '**Not Sensitive'** to organic enrichment, and the animals found within the biotope may be able to utilize the input of organic matter as food, or are likely to be resistant of inputs at the benchmark level.

Physical Pressures

	Resistance	Resilience	Sensitivity
Physical loss (to land or freshwater habitat)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

All marine habitats and benthic species are considered to have a resistance of '**None**' to this pressure and to be unable to recover from a permanent loss of habitat (resilience is '**Very Low'**). Sensitivity within the direct spatial footprint of this pressure is therefore '**High**'. Although no specific evidence is described confidence in this assessment is high, due to the incontrovertible nature of this pressure.

	Resistance	Resilience	Sensitivity
Physical change (to another seabed type)	None Q: High A: High C: High	Very Low Q: High A: High C: High	High Q: High A: High C: High

If the mixed sediments were replaced with rock substrata, this would represent a fundamental change to the physical character of the biotope. The biotope would be lost and/or re-classified.

Sensitivity assessment: Resistance to the pressure is considered '**None**', and resilience '**Very low**'. Sensitivity has been assessed as '**High**'.

Physical change (to another sediment type)	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

Records indicate that SS.SMx.CMx.OphMx occurs on a range of substrata, often including boulders, pebbles, cobbles, gravel, sand and mud (Connor *et al*., 2004).The characterizing species of this biotope, the brittlestars, are epifaunal and not attached to the substratum, and therefore unlikely to be adversely affected by a change in one Folk class from mixed sediment to mud and sandy mud, for example.

Sensitivity assessment: A change in the seabed type at the benchmark level is unlikely to affect the characterizing species, which have been recorded on a wide variety of substrata, ranging from bedrock, through boulders and cobbles to gravel, sand and mud (Hughes, 1998b). Resistance is therefore assessed as '**High**' and resilience as **'High'** (by default), and the biotope is considered **'Not Sensitive'** at the pressure benchmark.

Habitat structure changes - removal of substratum (extraction)	None Q: Medium A: Medium C: Medium	Medium Q: Medium A: Medium C: Medium	Medium Q: Medium A: Medium C: Medium

Extraction of substratum to 30 cm is likely to result in the removal of the biological community along with the substrata, including the characterizing species, the brittlestars, and other component infaunal and epifaunal species.

Sensitivity assessment. Due to the nature of this pressure it is highly likely that a large amount of the sediment would be removed along with the biological community, resulting in the removal of the biotope. Resistance is assessed as **'None'** and resilience as **'Medium'** with a sensitivity of **'Medium'**

Abrasion/disturbance of the surface of the substratum or seabed	Low Q: High A: High C: High	Medium Q: High A: High C: High	Medium Q: High A: High C: High

A review by Jennings & Kaiser (1998) suggested that the main direct effects of fishing on marine ecosystems usually include scraping, scouring and re-suspension of substratum. Brittlestars are epifaunal and have fragile arms so are likely to be directly exposed and damaged by abrasion. Brittlestars can tolerate considerable damage to arms and even the disk without suffering mortality and are capable of arm and even some disk regeneration (Sköld, 1998). Fishermen tend to avoid brittlestar beds since the animals clog their nets (Jones *et al*., 2000). However, a passing scallop dredge is likely to remove, displace, or damage brittlestars caught in its path. Although several species of brittlestar were reported to increase in abundance in trawled areas (including *Ophiocomina nigra*), Bradshaw *et al*. (2002) noted that the relatively sessile *Ophiothrix fragilis* decreased in the long-term in areas subject to scallop dredging. Overall, a proportion of the population is likely to be damaged or removed. An average of 36% of individuals in five British brittlestar beds were regenerating arms (Aronson, 1989) showing that the beds can persist following exposure to a pressure.

SS.SMx.CMx.OphMx occurs in a variety of substrata including boulders, cobbles, pebbles, gravels, sand and mud (Connor *et al*., 2004). Sediment re-suspension is therefore likely to occur, with associated consequences for the biological community (see suspended solids and siltation pressures), as well as potential changes in the sediment characteristics of the seabed as a result of the repeated non-targeted removal of sediment (Bradshaw *et al.*, 2002, references therein). Furthermore, e.g. cobbles and pebbles present, are likely to be moved and turned as a result of the passing dredge, leading to further damage to the epifaunal communities.

Sensitivity assessment. Epifaunal species and communities are considered to be amongst the most vulnerable to bottom gears (Jennings & Kaiser, 1998) and the impact of surface abrasion will depend on the footprint, duration and magnitude of the pressure. Based on the evidence, resistance to a single abrasion event is assessed as '**Low'** and resilience as **'Medium'**, so that sensitivity is assessed as '**Medium**'. However, Veale *et al.* (2000) suggested that the abundance, biomass and production of epifaunal assemblages decreased with increasing fishing effort suggesting that, resistance and recovery of the biotope's species are likely to vary with pressure intensity. Resistance and resilience will therefore be lower (and hence sensitivity greater) to repeated abrasion events.

Penetration or disturbance of the substratum subsurface	None Q: Medium A: Medium C: Medium	Medium Q: High A: High C: High	Medium Q: Medium A: Medium C: Medium

Damage to the seabed's sub-surface is likely to remove both the infaunal and epifaunal communities that occur in this biotope. Additionally, penetrative activities (e.g. anchoring, scallop or suction dredging) are likely to remove or displace the cobbles, pebbles, or small boulders that occur in this biotope. As a result the biotope could be lost or severely damaged, depending on the scale of the activity (see abrasion above). Therefore, a resistance of **'None**' is suggested. Resilience is probably '**Medium'** therefore the biotope's sensitive to this pressure if likely to be **'Medium'**.

Changes in suspended solids (water clarity)	High Q: Medium A: Medium C: Medium	High Q: Medium A: Medium C: Medium	Not sensitive Q: Medium A: Medium C: Medium

Ophiothrix fragilis and *Ophiocomina nigra* are passive suspension feeders and a significant supply of suspended organic material is needed to meet the energetic costs of the great numbers of individuals in a brittlestar bed. Brittlestar beds occur in a variety of water flow regimes from sea lochs to more energetic coastal sites (Connor *et al.*, 2004) so are likely to tolerate a variety of different suspended sediment concentrations. For example, dense britlestar beds occur in the Dover Straits, where the concentration of suspended particles in the water column changes between 18-32 mg/l annually (Davoult & Gounin, 1995). Although some brittlestar species are able to perceive differences in light and dark, visual perception is limited (Tillin & Tyler-Walters, 2014) and brittlestars are unlikely to be directly affected by changes in light resulting from a change in turbidity and suspended solids.

However, local increases in turbidity in waters previously within the photic zone, may alter local abundances of phytoplankton and surface diatoms and the zooplankton and other small invertebrates that feed on them. Davoult & Gounin (1995) found that the growth rate of *Ophiothrix* in the Dover Strait was maximal in April/May, coinciding with the spring phytoplankton bloom, which suggests that an increase in suspended solids and resulting increase in turbidity may indirectly reduce feeding efficiency in brittlestars. Nonetheless, since phytoplankton may arrive from distant sources and brittlestars may also feed on organic detritus any effects are expected to be small. Additionally, *Ophiothrix fragilis* has a low respiration rate and can tolerate considerable loss of body mass during reproductive periods (Davoult *et al.*, 1990) suggesting that this species may tolerate feeding restrictions.

Sensitivity Assessment: The evidence presented suggests that an increase in suspended organic matter may be beneficial by providing increased food material while a decrease in suspended sediment may reduce food supplies to brittlestar beds. Additionally, increases in suspended solids that involve increase of inorganic particles may interfere with the feeding of brittlestars (Aronson, 1992 cited in Hughes, 1998b), particularly in non-current swept areas. However, the biotope occurs in a wide range of conditions and are likely to be adapted to respond to changes in suspended solids at the pressure benchmark and the overall species richness in the biotope is not likely to change. Resistance is therefore assessed as **'High'** and resilience as '**High'**, so the biotope is assessed as '**Not Sensitive'** to a change in turbidity at the pressure benchmark.

Smothering and siltation rate changes (light)	Low	Medium	Medium
	Q: Medium A: Medium C: Medium	Q: Medium A: Medium C: Medium	Q: Medium A: Medium C: Medium

Material in suspension can affect the efficiency of filter and suspension feeding (Sherk & Cronin, 1970; Morton, 1976). Effects can include abrasion and clogging of gills, impaired respiration, clogging of filter mechanisms, and reduced feeding and pumping rates. Dense beds of brittlestars tend not to persist in areas of excessive sedimentation, because high levels of sediment foul the brittlestars feeding apparatus (tube feet and arm spines), and ultimately suffocates them (Schäfer, 1962 cited in Aronson, 1992). Aronson (1989) referred to the demise of Warner's (1971) *Ophiothrix* bed in Torbay, and tentatively suggested it was due to increased sedimentation caused by the localised dumping of construction materials (Aronson, 1989).

In areas of high water flow dispersion of fine sediments may be rapid and this could mitigate the magnitude of this pressure by reducing the time exposed, where 'light' deposition of sediments is likely to be cleared in a few tidal cycles.

In exposed situations suspended material can cause scour, but this is normally a result of the temporary re-suspension of relatively coarse bottom material rather than of fine material in long-term suspension.

Sensitivity assessment. This pressure is not considered to alter the physical reef habitat but there may be effects on the biological community. Habitat resistance is assessed as '**Low'** given that the key characterizing species of brittlestars are likely to be affected by a single discrete event of light deposition of fine materials that is not removed in the short-term by water movement. Resilience is likely to be '**Medium**' and the habitat sensitivity is assessed as '**Medium**'.

Smothering and siltation rate changes (heavy)	Low	Medium	Medium
	Q: Medium A: Medium C: Medium	Q: Medium A: Medium C: Medium	Q: Medium A: Medium C: Medium

Material in suspension can affect the efficiency of filter feeding (Sherk & Cronin, 1970; Morton, 1976). Effects can include abrasion and clogging of gills, impaired respiration, clogging of filter mechanisms, and reduced feeding and pumping rates. Dense beds of brittlestars tend not to persist in areas of excessive sedimentation, because high levels of sediment foul the brittlestars feeding apparatus (tube feet and arm spines), and ultimately suffocates them (Schäfer, 1962 cited in Aronson, 1992). Aronson (1989) referred to the demise of Warner's (1971) *Ophiothrix* bed in Torbay, and tentatively suggested it was due to increased sedimentation caused by the localised dumping of construction materials (Aronson, 1989).

In areas of high water flow dispersion of fine sediments may be rapid and this could mitigate the magnitude of this pressure by reducing the time exposed, where 'heavy' deposition of sediments is likely to be cleared in a few tidal cycles.

In exposed situations suspended material can cause scour, but this is normally a result of the temporary re-suspension of relatively coarse bottom material rather than of fine material in long-term suspension.

Sensitivity assessment. The brittlestars forming the dense beds characterizing this biotope are likely to be adversely affected by the smothering effect of a 'heavy' deposition of 30 cm of sediment in a single discrete event. Habitat resistance is assessed as '**Low**' and recovery is probably '**Medium**' and the habitat sensitivity is assessed as '**Medium**'.

Litter	Not Assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR	Not assessed (NA) Q: NR A: NR C: NR

Not assessed.

Electromagnetic changes	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

'**No Evidence'** is available on which to assess this pressure.

Underwater noise changes	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

There is little known about the effects of underwater sound on marine invertebrates. Although there are no records of brittlestars reacting to noise, sound vibrations may trigger some response. However, at the level of the benchmark the biotope is not likely to be sensitive to noise pollution. For example, brittlestar beds have been recorded from Kinsale Harbour (Hughes, 1998b) on the south coast of Ireland where there is likely to be noise disturbance from passing boat traffic.

Sensitivity assessment: There is not enough evidence to assess this pressure.

Introduction of light or shading	High Q: High A: High C: High	High Q: High A: High C: High	Not sensitive Q: High A: High C: High

SS.SMx.CMx.OphMx is a circalittoral biotope (Connor *et al.*, 2004) and therefore, not directly dependent on sunlight. Although some brittlestar species are able to perceive differences in light and dark, visual perception is limited (Tillin & Tyler-Walters, 2014) and this suggests that the brittlestars are unlikely to be directly affected by change in light.

Sensitivity assessment. The biotope is considered to have '**High**' resistance and, by default, '**High**' resilience and therefore is '**Not Sensitive'** to this pressure.

Barrier to species movement	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

'Not Relevant' to biotopes restricted to open waters.

Death or injury by collision	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

'Not Relevant' to seabed habitats.

Visual disturbance	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Ophiothrix fragilis and other brittlestars and starfish are likely to have poor facility for visual perception and consequently are probably not sensitive to visual disturbance. Movement of a hand near to *Ophiothrix fragilis*, for example, elicits no escape response (Sköld, 1998). Although some other species, such as crabs and fish, may respond to visual disturbance such behaviour is not likely to have an impact on the nature and function of a brittlestar bed so the biotope is expected to be not sensitive to the factor. Therefore, this pressure is considered **'Not Relevant'.**

Biological Pressures

	Resistance	Resilience	Sensitivity
Genetic modification & translocation of indigenous species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

The key characterizing species in the biotope are not cultivated or likely to be translocated. This pressure is therefore considered '**Not Relevant**'.

Introduction or spread of invasive non-indigenous species	No evidence (NEv) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	No evidence (NEv) Q: NR A: NR C: NR

There is no evidence on the presence of non-indigenous species or impacts of non-indigenous species relevant to this biotope. This pressure is therefore not assessed, based on '**No Evidence**'

Introduction of microbial pathogens	High Q: Medium A: Low C: High	High Q: High A: High C: High	Not sensitive Q: Medium A: Low C: High

Introduced organisms (especially parasites or pathogens) are a potential threat in all coastal ecosystems. So far, brittlestar beds have not been affected. Dense aggregations of brittlestars would offer ideal conditions for the rapid spread of pathogenic organisms or parasites, but so far no examples of this have been recorded. However, several examples are known of echinoderm populations that have been massively reduced by sudden outbreaks of epidemic disease. Cases include the mass mortality of the sea urchin *Diadema antillarum* throughout the Caribbean as a result of infection by a water-borne pathogen (Lessios, 1988), and the decimation of urchin populations in the North Atlantic by parasitic amoebae and nematodes (Hagen, 1997). Epidemic disease should therefore be considered as having the potential to significantly affect populations of bed-forming brittlestars (Hughes, 1998b), as even widespread and abundant species can be vulnerable.

Lynch *et al*. (2007) investigated the possible role of benthic macroinvertebrates and zooplankton in the life cycle of *Bonamia ostrea*, a parasite the European flat oyster *Ostrea edulis*. Their laboratory studies found that the brittlestar *Ophiothrix fragilis* was a passive carrier of the parasite but is not infected. Brittlestar mortality in their treatments was not explained, and it was uncertain if parasite infection was to blame. However, they found where the oysters co-habited with the brittlestars, oyster infection by the parasite was lower. It is, however, unlikely that the oyster-specific parasite would be responsible for the brittlestar mortalities recorded (Lynch *et al*., 2007).

Sensitivity assessment.The evidence suggests that brittlestars may be exposed to pathogens, but that no mortality has been reported. Therefore brittlestar beds probably have '**High**' resistance to this pressure. By default resilience is assessed as '**High**' and the biotope is classed as '**Not Sensitive'**.

Removal of target species	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR	Not relevant (NR) Q: NR A: NR C: NR

Brittlestar beds are currently not targeted by commercial fisheries and hence not directly affected by this pressure (Tillin & Tyler-Walters, 2014). This pressure is therefore considered '**Not Relevant**'.

Removal of non-target species	Low Q: Medium A: Low C: High	Medium Q: High A: High C: High	Medium Q: Medium A: Low C: High

Fisheries tend to avoid brittlestar beds since the animals clog nets (Jones *et al*., 2000). However, brittlestars may be damaged or directly removed by static or mobile gears that are targeting other species. Direct, physical removal is assessed under abrasion and penetration pressures. The sensitivity assessment for this pressure considers any biological and ecological effects resulting from the removal of non-target species.

Although several species of brittlestar (including *Ophiocomina nigra*) were reported to have increased in abundance in trawled areas, Bradshaw *et al.* (2002) noted that the relatively sessile *Ophiothrix fragilis* decreased in the long term in areas subject to scallop dredging. The bed may contract in size as individual brittlestars move to re-establish contact with neighbours or the number of low density patches could increase. If water currents were very strong some animals may be washed away as the support provided by other individuals in dense aggregations decreases. In addition, commercial fisheries may discard damaged or dead non-target species. This could result in increased available food supply to scavenging brittlestars but may also attract mobile predators and scavengers including fish and crustaceans to habitats supporting brittlestars, which may alter predation rates.

Sensitivity assessment: Once extraction or fishing has stopped, brittlestars that remain in the bed are likely to be able to re-establish the density observed prior to the event. Based on the evidence presented, the resistance of the biotope is considered to be '**Low**', with **'Medium'** resilience and therefore the biotope is considered to have '**Medium**' sensitivity to this pressure.

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